Chapter 3 Selecting a Gas Use Option

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The purpose of this chapter is to examine how biogas can be used at a farm. Electricity generation with waste heat recovery (cogeneration) is usually the most profitable option for a farm. However, other options may be profitable in certain circumstances. This chapter serves as a reference to determine what factors need to be considered when determining how to use the biogas.

There are several important factors to be considered when selecting a biogas use option:

- **What type of energy does the farm use?** Farms use electricity, natural gas, propane, or fuel oil energy. Biogas can be used to replace purchased energy for electricity, heating, or cooling. For most farms, the most profitable biogas use option will be to fuel an internal combustion (IC) engine or gas turbine driven generator to produce electricity. Other options include using biogas to fuel forced air furnaces, direct fire room heaters, and adsorption chillers.

- **How much energy does the farm use and when?** Farm energy requirements will vary daily and seasonally. For example: heating and air conditioning are seasonal uses; most lighting is used at night; milking two or three times a day for four hours is a very uneven use of electricity; and hog barn ventilation varies by the time of day and season. Most farm operations have the potential to produce most or all their energy needs if they collect and convert <u>all</u> suitable manure produced to biogas.

- **Will the potential energy production offset energy needs?** When matching biogas availability to energy requirements, it is important to keep in mind that biogas is produced year round and biogas storage for more than several hours is expensive. Therefore, the most cost-effective biogas use option is one that uses the gas year round. Direct gas use options, such as space heating and cooling, vary seasonally. Furthermore, these options can use only a small fraction of the potential energy from biogas. Designing a system for such a limited use will generally not be cost effective, unless the system is for purposes of odor control. Large farms may be able to match biogas energy production more closely to energy use than will small farms.

- **Is electricity the primary energy requirement?** In the United States, electricity is the largest stationary use of energy on farms. Electric motors for pumps, fans, and motors, as well as lights are generally in use all year round. Usually electricity production for on-farm use is the most viable option.

- **Can the engine generator be serviced?** Easy access for maintenance tasks and ready availability of parts and services are critical considerations.

The potential gas use options are discussed in turn and summarized in Exhibit 3-1.

For further discussion of gas use options, review *The Handbook of Biogas Utilization*, available from General Bioenergy, P.O. Box 26, Florence, Alabama 35631, Phone: (256) 740-5634.

Exhibit 3-1 Summary of Potential Gas Use Options

Option	Applicability
Electricity Generation	Suitable for most facilities (electricity accounts for approximately 70 to 100% of energy use).
Direct Combustion	
Boiler/Furnace	Seasonal use or specialized situations
Chiller	Dairy refrigeration (approximately 15 to 30% of dairy electricity use); seasonal cooling; and specialized situations

3-1. Electricity Generation

Electricity can be generated for on-farm use or for sale to the local electric power grid. Modern dairies and swine facilities require a significant amount of electricity to operate equipment. Hog nurseries require a large amount of circulating heat, but few have hot water heat. Almost all use electric heat lamps and supplemental propane heaters to maintain a suitable temperature. Similarly, 30 percent of dairy electricity consumption is used to cool milk.

The most commonly used technology for generating electricity is an internal combustion engine with a generator. Recovering waste heat from these engines can provide heating, hot water for farm use, or hot water for digester heating thereby improving the overall energy efficiency of the system.

3-1.1 Electricity Generation System Components

Typical electricity generation systems consist of: (1) an IC engine or gas turbine; (2) a generator; (3) a control system, and (4) an optional heat recovery system. Each component is discussed briefly, in turn.

1. **IC Engine or Gas Turbine.** Both IC engines and gas turbine driven generators sets are being used to generate electricity from biogas.

   - *IC Engine.* Natural gas or propane engines are easily converted to burn biogas by modifying carburetion and ignition systems. Natural gas engines are available in virtually any capacity that is required. The most successful engines are industrial natural gas engines that can burn wellhead natural gas. A biogas fueled engine generator will normally convert 18 - 25 percent of the biogas BTUs to electricity, depending on engine design and load factor. Gas treatment is not necessary if proper maintenance procedures are followed. Biogas engines less than 200 horsepower (150 kW) generally meet the most stringent California pollution restrictions without modification if run with a lean fuel mixture. Exhibit 3-2 shows a typical engine-generator set.

   - *Gas Turbines.* Small gas turbines that are specifically designed to use biogas are also available. An advantage to this technology is lower NOx emissions and lower maintenance costs, however energy efficiency is less than with IC engines and it costs more.

2. **Generator.** There are two types of generators that are used on farms: induction generators and synchronous generators.

   - *Induction Generator.* An induction generator will operate in parallel with the utility and cannot stand alone. Induction generation derives phase, frequency, and voltage from the utility. Negotiations with a utility for interconnection of a small induction generator are generally much easier.

   - *Synchronous Generator.* A synchronous generator will operate either isolated or in parallel. The synchronous generator can provide electricity to the farm if the utility is shut down. Synchronous parallel generation requires a sophisticated interconnection to match generator output to utility phase, frequency, and voltage. This is typically more expensive than controls for an induction generation.

   Most farm-scale systems will use induction generators. The options for electricity generation modes (isolated versus parallel) are discussed further in Section 3-1.2.

3. **Control System.** Controls are required to protect the engine and to protect the utility. These systems are well developed. Control packages are available that shut the engine off due to mechanical problems such as high water temperature or low oil level. The control system will also shut off the engine if the utility power is off, or if utility electricity is out of its specified voltage and frequency range. It is important to recognize that the control system selected must be designed to operate in a damp environment where corrosive gases, such as ammonia, may be present.

4. **Waste Heat Recovery.** Approximately 75 percent of fuel energy input to an engine is rejected as waste heat. Therefore, it is common practice to recover engine heat for heating the digester and providing water and space heat for the farm. Commercially available heat exchangers can recover heat from the engine water cooling system and the engine exhaust. Properly sized heat exchangers will recover up to 7,000 BTUs of heat per hour for each kW of generator load, increasing energy efficiency to 40 - 50 percent.

3-1.2 Electricity Generation Options

A farm may choose to use a stand-alone engine-generator to provide all or part of its own electricity as an "isolated" system (disconnected from the utility). It may also operate connected to and interfacing electricity with the utility, "in parallel". Most farms will opt for parallel power production.

- **Isolated Power Production.** An isolated system must be able to function continuously, without interruption, to meet fluctuating levels of electricity demand while maintaining a smooth and steady 60 cycle current. Varying electric loads or large motor starting loads can lead to drift in the 60 cycle current. Drift results in wear on the motors, speed up or slow down of clocks and timers, and operating problems with computers and programmable logic controllers.

  Isolated systems require a sophisticated control system and a gas reservoir to meet changing loads. They are generally oversized to accommodate the highest electrical demand while operating less efficiently at average or partial load.

  The primary advantage of an isolated power production system is that it is free from the utility.

  The disadvantages of isolated power production include: (1) having to operate and maintain the system at all times; (2) purchasing oversized and costly equipment, if high quality electricity is needed; (3) purchasing and maintaining a backup generation system or paying the utility for backup service, if electricity is critical to farm operations; (4) requiring an engine that is sized to meet maximum farm load (varying load means that the engine has to increase or decrease output implying that the engine is operating inefficiently); and (5) managing electricity use to reduce demand fluctuations.

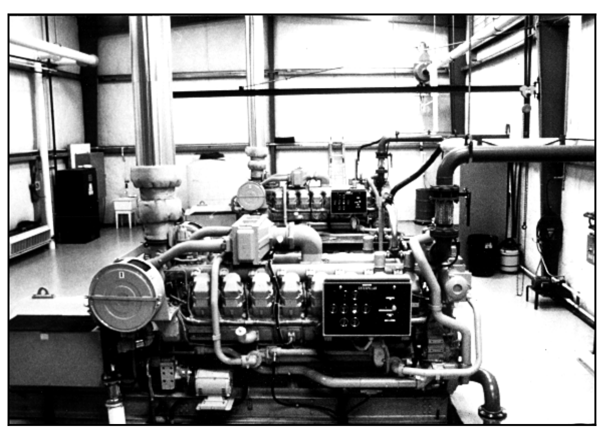
- **Parallel Power Production.** A parallel system is directly connected to the utility and matches the utility phasing, frequency and voltage so the farm produced electricity blends directly with the utility line power. A utility interconnection panel with safety relays is required to operate in parallel and to disconnect the farm generator if there is a problem with either utility or farm generation.

  Parallel operation allows the farm generator to run at a constant output regardless of farm demand. Constant output allows more efficient use of biogas and less wear on the engine. The engine-generator can be sized for the biogas availability as opposed to farm requirements.

  The farm buys power when under-producing and sells power when overproducing. The utility is the backup system if engine maintenance is required.

The key issue in developing a profitable biogas recovery system is the value of the energy to the owner. A careful review of utility rates and interconnection requirements are necessary prior to selecting the operating mode. Rate negotiation is appropriate for farm scale projects as most rules are set

Exhibit 3-2 Typical Engine-Generator Set



up for very large independent power producers. Chapter 5 discusses how a livestock producer should negotiate with a utility. FarmWare can help you understand the impact of utility rates on electrical costs and expected revenues from the project.

3-2. Direct Combustion

The recovered biogas can be used directly on-site as a fuel. Equipment that normally uses propane or natural gas such as boilers, forced air furnaces, and chillers, can be modified to use biogas. Typical farms use only a limited amount of these fuels compared to electricity.

3-2.1 Heating

Heating is usually a seasonal operation. Boilers and forced air furnaces can be fired with biogas to produce heat. Although this may be an efficient use of the gas, it is generally not as convenient as electricity. Nevertheless, in some situations it may be a best option.

- **Boilers.** Thousands of biogas-fired boilers are in use at municipal waste treatment plants in the United States, where they provide hot water for building and digester heat. Conversion efficiencies are typically at 75 to 85 percent. Several have been installed on farm digesters. Farms require hot water year round, but there is typically more biogas available than hot water required. Farrow to wean and farrow to nursery hog farms in cold climates are the only type of farm where heat requirements could consume most or all of the available biogas production potential. Exhibit 3-23 shows.

  A cast iron natural gas boiler can be used for most farm applications. The air-fuel mix will require adjustment and burner jets will have to be enlarged for medium BTU gas. Cast iron boilers are available in a wide range of sizes, from 45,000 BTU/hour and larger. Untreated biogas can be burned in these boilers. However, all metal surfaces of the housing should be painted. Flame tube boilers with heavy gauge flame tubes may be used if the exhaust temperature is maintained above 300°F to minimize condensation. High hydrogen sulfide (H_2S) concentration in the gas may result in clogging of flame tubes.

- **Forced Air Furnaces.** Forced air furnaces could be used in hog farms in place of direct fired room heaters, which are commonly used in hog farrowing and nursery rooms. A farm will typically have multiple units. Biogas fired units have not been installed in the United States due to a number of reasons. These heaters are available and in use in Taiwan.

3-2.2 Chilling/Refrigeration

Dairy farms use considerable amounts of energy for refrigeration. Approximately 15 to 30 percent of a dairy's electricity load is used to cool milk. Gas-fired chillers are commercially available and can be used for this purpose. For some dairies, this may be the most profitable option for biogas utilization.

Gas-fired chillers produce cold water for milk cooling or air conditioning. Dairies cool milk every day of the year. Chilled water or glycol can be used in milk precoolers in place of well water. Units are under development that should produce glycol at temperatures less than 30^{o}F and allow direct refrigeration. A dairy generally requires 0.014 tons of cooling per hour of milking per cow per day. This is about 15 percent of the potential biogas production

Exhibit 3-3 Hot Water Mats Replace Heat Lamps in Farrowing Buildings for Additional Energy Savings

from the same cow (one ton of cooling = 12,000 BTU/hour).

Double effect chillers, producing hot and cold water simultaneously, are available for applications of over 30 tons and could be coupled with a heated digester.